XI. THE JURASSIC DINOSAUR DEPOSITS NEAR CANYON CITY, COLORADO.

By J. B. Hatcher.

Notwithstanding the great wealth of certain, indeed of several, of our Mezozoic horizons in dinosaurian remains and the exceptional vigor with which the bringing together and study of dinosaur bones have been pursued for the last quarter of a century in this country by Marsh, Cope, Baur, Osborn, Williston and others, and for an even longer period, though under much less favorable conditions, by British and European paleontologists, yet we are still ignorant of the complete osteology of all but a few of the many proposed genera of dinosaurs, while of the phylogeny of the various genera and species of the different families we know absolutely nothing. This is the more remarkable considering the progress that has been made in mammalian paleontology, where in many families, as for instance the horses, camels, and titanotheres, nearly every step in their development has been traced and can be pointed out with as much precision as can the different stages in the perfection of the modern steam engine, electric motor, or other mechanical device wherein the forces of nature have been made to serve the uses of man. This disparity in the progress of these two closely related branches of vertebrate paleontology has not been due to a lack of interest in dinosaur remains as such, for many of these animals by reason of their remarkable size and grotesque form have from their earliest discovery inspired almost universal interest. The difficulty in placing and keeping our knowledge of dinosaurs abreast with that of mammals has been due rather to the vastly greater difficulties encountered in bringing together sufficiently complete collections from the various localities and horizons to permit of a comparative study of the different forms from each. These difficulties arise from the great size of the individual animal in many genera and species, from the scarcity of dinosaur remains in many horizons and from the difficult nature and great expense of the work necessary for collecting dinosaurs. Moreover dinosaur remains have as a rule been found only in essentially one horizon in the same formation at any given locality, and when found at different and widely separated locali-

ties in the same formation it has thus far been found quite difficult to establish definitely the relative positions of such horizons within the same formation.

On visiting the bone quarries near Canyon City, Colorado, made classic by the researches of the late Professors O. C. Marsh and E. D. Cope, in the spring of 1900 shortly after taking charge of the Department of Vertebrate Paleontology in the Carnegie Museum, the striking advantages presented by this locality not only for collecting the remains of dinosaurs, but for determining the exact stratigraphic position of the various skeletons both with reference to each other and to the underlying Trias and overlying Cretaceous formations were at once apparent.

Perhaps in no other locality is the geological section from the base of the Trias to the top of the Cretaceous more complete than in the canyon of Four Mile, or Oil Creek, from the entrance to Garden Park, some eight miles east by north of Canyon City to the mouth of that canyon where it opens into the valley of the Arkansas River and thence across the valley to the foothills on the south side of the river, on a line about midway between the towns of Canyon City and Florence. The geological section along this line is remarkably complete and exceptionally well displayed, so that in passing down Four Mile Creek through Garden Park and the somewhat rugged canyon through which the creek flows on its way from the Park to the valley of the Arkansas River and thence across the river valley to the hills back of Florence there may be seen a continuous section commencing below with the brick red Triassic sandstones which form so conspicuous a feature in the bluffs on the west side of Garden Park and terminating above in the yellowish brown Laramie sandstones and Denver Beds of Cross and Eldridge found capping the bluffs and lower foothills on the south side of the Arkansas River. A brief description of the more important horizons shown in this section may not be out of place.

The Triassic.

To the Trias I refer the red sandstones just alluded to as so conspicuous in Garden Park. I have placed these sandstones in the Trias rather than the Carboniferous on no direct paleontologic evidence, but rather on account of their general resemblance to the red sandstones, which in other places underlie the Jura, and have by common consent been considered as belonging to the Trias. Dr. Whitman Cross has

designated this series as the Fountain formation and referred it to the Carboniferous on the evidence afforded by certain fossils found in certain thin seams of limestone interstratified with a similar red sandstone found in the western part of Colorado. Thus far no fossils are known from the red sandstone of Garden Park, and until we have some direct evidence as to their age it would seem as well to correlate them with the "red beds" everywhere so abundant about the eastern slopes and outliers of the Rockies and which have of late been generally considered as of Triassic age. These sandstones dip very gently to the southeast and pass beneath the surface at a point a little above the southern entrance to Garden Park. In their lower members they are of a uniform brick red color, fine grained, and do not differ materially from the Triassic sandstones found everywhere flanking the main ranges of the Rockies as well as surrounding all the detached or isolated upthrusts belonging to the same great mountain system, except for a decrease at this locality in the quantity of gypsum or selenite which usually accompanies the Triassic red beds of the West. Toward the top these sandstones become much harder, and coarser, the color is not so deep a red and in places they pass, toward the summit, into a very hard coarse-grained sandstone or conglomerate of a brownish gray color. I have been unable to detect any unconformity between the Triassic sandstones and the overlying Jurassic rocks in this locality, although a careful search might reveal such.

The Jurassic.

Immediately overlying the red sandstones are a series of brown sandstones, shales and marls with occasional thin seams or lenses of limestone. They have an aggregate thickness of perhaps 450 feet and the whole is about equally divided between sandstones, and shales or marls. The entire series is here referred to the Jurassic on the evidence afforded by the dinosaur remains found in them. These remains are found in considerable abundance at several horizons and occur both in the sandstones and the shales, while the limestone layers above referred to are as a rule very rich in the remains of small fresh water gastropoda and from one horizon great numbers of Unio shells and casts have been obtained in one of the marl beds. These invertebrate remains have been described by Dr. C. A. White in Bulletin 29 of the U. S. G. S. Unfortunately like most fresh water invertebrates they afford little evidence as to the exact age of the deposits from which they were derived.

Marsh has called these beds the *Atlantosaurus beds*, while Cross several years later named the same series the *Morrison formation*, referring it to the Juratrias. There would seem to be little doubt that the entire series may be very properly referred to the Jurassic on the evidence of the dinosaurian remains which they contain, all of which so far as at present known pertain to Jurassic types rather than Triassic. The beds of sandstone, marl and shale are not continuous, so that a section taken at any given point showing the arrangement of the different components would vary greatly from another taken at a different though not far distant place. The ripple-marks, cross-bedding and discontinuity of the component strata, as well as the presence of fossil footprints and the character of the invertebrate and plant remains found in the beds, all bear evidence of the prevailing conditions attending the deposition of the materials. These conditions will be discussed later when we come to speak of the bone deposits which they contain.

The sandstones, shales and marls of the Jura may be seen in the enclosing walls on either side of the southern half of Garden Park, and in the cañon of the creek below the park, which affords several splendid sections between the mouth of the cañon and the southern entrance to the Park. In general the beds have a gentle southerly dip, but within the cañon this dip and the general sequence of the strata is frequently obscured by numerous local faults and landslides. At the mouth of the cañon about four miles distant from Canyon City the strata are inclined at a high angle and soon pass beneath the surface.

CRETACEOUS.

The Dakota Sandstones.—Conformably overlying the Jurassic deposits is a series of yellowish-brown or whitish sandstones with occasional layers of shale. These sandstones and shales so closely resemble the underlying Jurassic deposits both as regards their physical appearance and constituent parts that it is impossible to definitely separate the two series, and any line of demarcation between the two deposits must be considered as somewhat arbitrary. Cross has placed the thickness of the Jurassic or Morrison formation at 350 feet, while to the Dakota he assigns a thickness of 300 feet. This appears to the writer as placing the base of the Dakota somewhat too low in the series, and I think by allowing so great a thickness as 300 feet for the Dakota they would be made to include the upper and perhaps a second

Dinosaur horizon in which remains of dinosaurs belonging to Jurassic types are quite abundant. I have thought best to assign a thickness of 450 feet to the Jurassic at this locality while limiting the Dakota to the uppermost 200 feet of the sandstone and shale series.

The Dakota may be seen as a rather thick, heavily bedded light brown or white sandstone capping the small detached tables which rise above the summits of the bluffs on the west side of the creek at the southern end of Garden Park. These sandstones are also conspicuous in the cañon below the Park, where they form the uppermost part of the cañon walls and usually present a bold face with sheer escarpments often from fifty to one hundred feet in height. In places they are very rich in the impressions of fossil leaves, but so far as at present known they are remarkably destitute of all remains of animal life, though a careful and continued search will doubtless yet bring to light remains of the terrestrial animal life that must have lived in the immediate region during their deposition. At the mouth of the cañon the rocks of the Dakota are inclined at a considerable angle and disappear beneath the surface. The Dakota has been generally assumed to be of fresh water origin, though the evidence in favor of this view has been of a negative rather than a positive nature. For the most part the materials of which these beds are composed would seem to have been deposited in fresh water, but there has lately been discovered some very strong evidence in favor of the marine origin of at least a portion of the series. This will be referred to later when we come to discuss the fossil deposits of the underlying series of sandstones and shales.

The Benton Shales.—The close of the period which witnessed the deposition of the Dakota sandstones was accompanied by a marked change in the physical conditions that prevailed over this region, as is abundantly emphasized by the nature of the materials composing the rocks of the succeeding formation as well as by the character of the fossils which they contain. For a long period during the Jurassic and early Cretaceous the surface of this region was maintained at an elevation for the greater portion of the time at least slightly above sea level and the sandstones and shales were laid down along the shores of adjacent seas, over the bottoms of smaller bodies of water or along the courses and over the flood plains of running streams. That some such conditions as the above attended the deposition of the materials constituting the rocks of the Dakota and Jurassic formations is abun-

dantly evidenced by the frequent examples of cross-bedding and ripple-marked surfaces exhibited by the sandstones, by the want of continuity in the different strata, by the character of the invertebrate fauna, the character of the vertebrate fauna and by the manner in which the complete or dismembered skeletons and isolated bones of the latter have been entombed.

At the close of the Dakota this entire region was subjected to a greater subsidence and was uniformly covered by a great sea, save perhaps for a few small islands. Evidence of this subsidence and the ingress of the sea consequent upon it, is seen in the uniform nature of the several hundred feet of shales and limestones, with at this locality a rather meager marine fauna, which overlie the Dakota sandstones with apparent conformity and constitute the Benton shales or lower member of the Colorado formation. Toward the top these limestones and shales are replaced by a few feet of brown sandstones closely resembling in general appearances the Dakota sandstones, though separated from them by from 400 to 500 feet of marine shales and limestones. This stratum of Benton sandstone may be seen on the north side of a small bluff just below the mouth of Wilson Creek on the west side of Oil Creek where the wagon road from Canyon City to Garden Park passes around the end of a low hog-back about one-quarter of a mile below the mouth of the cañon. The softer shales and limestones of the Benton are here obscured by the secondary deposits in the narrow valley of Wilson Creek which at this point discharges into Oil Creek, or Four Mile, as the latter is locally more generally known. The valley of Wilson Creek for some distance above its mouth follows the strike of the inclined strata, and owing to the greater resistance to erosion offered by the Dakota sandstones and the very similar layer of brown sandstone just referred to as occurring at the top of the Benton the breadth of the valley of this creek is here determined by the total thickness of the more easily eroded Benton shales, along the upturned edge of which the stream has cut its channel, following the line of least resistance.

The Niobrara.—Immediately and conformably overlying the stratum of brown sandstone just mentioned as occurring at the top of the Benton series there is a bed of shale about twelve feet thick followed by about thirty feet of fine-grained (magnesian?) limestone. This limestone is much jointed and is divided into a number of different strata separated by thin seams of shale. This is one of the most continuous

and easily recognizable horizons in the entire section and its materials are utilized quite extensively for the manufacture of Portland cement, large mills having been erected for that purpose at Portland a few miles below Florence on the Arkansas River. These limestones are overlaid by several hundred feet of dark colored, friable, arenaceous shales which toward their summit assume a yellowish color and pass gradually into a stratum of rather soft, yellow chalk not unlike in general appearance the softer strata of the chalks of central and western Kansas. The entire series commencing with the twelve feet of shale immediately overlying the brown sandstone at the top of the Benton, including the limestone and superimposed shales and terminating with the chalks just mentioned, constitutes the Niobrara or upper member of the Colorado formation. They are all well shown in the hills to the west of the road which leads from Canyon City to Garden Park about a half mile below the mouth of Oil Creek cañon.

The Pierre Shales.—Conformably overlying the chalks are a series of usually quite soft, fine-grained and finely laminated shales of great thickness and with numerous large concretions and septaria quite similar in form and structure to those found so abundant in the Pierre shales farther north. These shales doubtless belong to the lower member of the Montana formation, and while no direct evidence was found as to their exact age, I have referred them to the Pierre. They are well shown in the abandoned railway cuts on the projected and partially constructed road from Canyon City to Cripple Creek, where it passes over the low divide between Oil Creek and Canyon City, as also in the bluffs south of the Arkansas River, where they are overlaid by a series of sandstones and shales in which are perhaps represented rocks belonging to both the Fox Hills, Laramie and Denver formations, though of the existence of the former I was not able to satisfy myself.

The Bone Quarries in the Jurassic at Garden Park.—Fossil bones were first discovered in the Jurassic of this locality by the family of Mr. M. P. Felch in 1876. Through the local and Denver newspapers the attention of Professor Marsh was called to the locality and in the spring of 1877 Mr. S. W. Williston was sent by Professor Marsh to Canyon City to investigate the alleged discoveries. Mr. Williston at once recognized the importance of the locality and nature of the contained animal remains and began immediately the unearthing of the dinosaurian fossils. The quarry opened by Dr. Williston was worked

for several years for Professor Marsh under the very careful and skillful supervision of Mr. M. P. Felch, who showed a marked degree of appreciation of the importance of the remains and met and overcame the many difficulties attending their disentombment in a most commendable manner. Shortly after Professor Marsh began his operations at this locality Professor Cope also became interested and sent collectors to the same field to make further investigations. Cope's collectors were successful in finding rich deposits of Dinosaur remains in the same locality, but at considerably higher horizons, and these were successfully worked by Professor Cope for a number of years. In 1884 all work at this locality was abandoned and nothing further was done here in the way of collecting dinosaurs for sixteen years. In the spring of 1900 the present writer visited the locality and inspected the

FIG. 1. North end of Marsh quarry. The man in the foreground is standing on the bed of the quarry just below the bone-bearing horizon. The man above is standing on the layer of sandstone above the one containing the dinosaurian remains.

abandoned quarries of Marsh and Cope as well as making some further examinations with a view to determining, if possible, the vertical distribution of dinosaur remains throughout the beds. After a very superficial examination it became apparent that there were several distinct fossil-bearing horizons and that this locality more than any other offered very superior advantages for securing materials which would be of exceptional value in tracing the development of the different dinosaurian genera, owing to the various horizons at which the fossils are to be found and the ease with which the relative position of these various horizons can be determined. With this end in view rather than for the sole purpose of obtaining dinosaur bones, steps were at once taken to reopen the old quarries so long abandoned and to establish new horizons.

The Marsh Quarry.

Under the above name the locality most worked by Professor Marsh is referred to and from it were secured all the skulls and several of the most complete skeletons of Jurassic dinosaurs figured and described by him. He only abandoned it after the expense necessary to operate it had become so great, through the amount of material to be removed from above the bone-bearing horizon, that it was deemed no longer profitable. Both Mr. Felch and Mr. Smith, who had last worked the quarry for Marsh, represented to the writer that bones were seemingly just as abundant at the close of operations as at any time during the progress of the work. After this assurance from these gentlemen I decided to reopen this quarry at once. I was further led to this decision by the fact that the bone-bearing horizon in the quarry lies in the trough of a basin-shaped lens of sandstone, the bottom of which evidently owes its configuration to its having been deposited in a rather deep excavation in the surface of the underlying clays, which then formed the bottom of some stream or other shallow body of water. This basin, enclosed by an impervious stratum of clay, caused the formation of a bog or bed of quicksand thus endangering the lives of such animals as chanced to wander that way. The position occupied by this lens of sandstone in reference to the surface of the underlying clays is shown in the photograph of the front of the quarry reproduced in Fig. 2. The work of reopening the quarry was commenced November 1, 1900, and the bone-bearing horizon was laid bare over a strip sixteen feet wide and running the entire length of the quarry, or about seventy feet. At the upper end fully twenty feet of rock had

to be removed consisting largely of very hard sandstone. Already much good material has been secured belonging for the most part to Morosaurus, Stegosaurus, and Allosaurus.

In this quarry the bones are for the most part found in a very hard layer of sandstone, though they occasionally extend down for a short distance into the underlying clays. The bone-bearing stratum is

FIG. 2. View of face of south end of Marsh quarry showing depressed nature of base of sandstone lens. Under the tarpaulin on the left may be seen boxes of fossils ready for shipment.

about 150 feet above the red Triassic sandstones and the quarry is located about eighty rods below the house of Mr. Felch at the entrance to Garden Park. It is on the east side of the dry gulch that puts into Oil Creek just below the bridge by which the wagon road crosses that stream and about 100 yards above the mouth of the gulch. About thirty feet below this is a second bone-bearing horizon, while in the rather thick layer of clay just below the sandstone of the Marsh quarry are thin seams of limestone with numerous fresh water gasteropods. Across the gulch and about 100 yards above the Marsh quarry, in a

layer of marl at a somewhat lower horizon, are abundant remains of Unios belonging to various species.

The position and manner in which many of the bones lie in this quarry would indicate that the animals to which they belonged lived and met their death in the immediate vicinity if not on the exact spot where they are now found. Moreover, the frequent examples of

FIG. 3. The "Nipple" from the north showing in the foreground the trench cut by Professor Cope in collecting Dinosaur remains.

ripple marks, cross-bedding and other characteristics already referred to bear evidence that this immediate region was the habitat of these animals during Jurassic times and that the sediments constituting the rocks were accumulated not over the bottom of a great inland sea or lake, but rather on the bottoms, along the shores and over the flood

plains of lakes and rivers situated in a slightly elevated and level rather than mountainous region.

About two hundred and fifty feet above the level of the Marsh quarry and on the same side of Oil Creek, but three quarters of a mile distant from the Marsh quarry there is a thick stratum of chocolate-colored shale best shown in a small rounded butte, locally known as the "Nipple." This butte stands on the crest of the bluff above Oil Creek and is shown in the photographs reproduced in Figs. 3 and 4. It is perhaps 30 ft. in height and is composed entirely of a homogeneous stratum of chocolate-

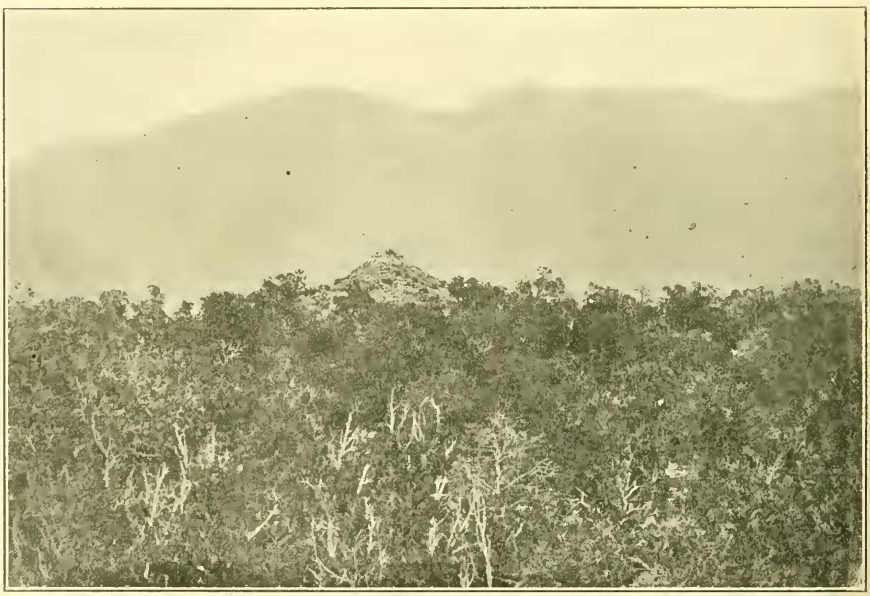

FIG. 4. View from near Cope quarry with the "Nipple" in the middle foreground and Cooper Mountain in the distance. Garden Park lies between the crest of the bluff, indicated by the line of trees on either side of the "Nipple," and Cooper Mountain in a depression about 600 feet below the "Nipple."

colored shale. This rests on a stratum of sandstone and is capped by another layer of sandstone as shown in the photographs. The base of this conical hill is about an acre in extent and everywhere about its base the remains of dinosaurs crop out in great abundance. Work has already been commenced at this locality and it is proposed to remove with plow and scraper this entire hill and thus lay bear the bone-bearing horizon over a large area.

About one quarter of a mile southwest of the "Nipple" near the top of this same thirty feet of chocolate-colored shale and just beneath a thick layer of white sandstone, which is generally placed as the base of the Dakota, is an old abandoned quarry worked by Messrs. Lucas and Russell for the late Professor Cope, and from which they recovered for him the beautiful skeleton of Camarasaurus now in the American Museum of Natural History in New York. This is a distinctly higher horizon than the one at the "Nipple." A view of the abandoned workings at this quarry may be seen in Fig. 5 where the light colored Dakota sandstones appear resting on the dark, chocolate-colored shales which bear the dinosaurian remains. Owing to the poor light in the deep trench leading to the quarry the shaly structure of the latter is not shown in the photograph.

FIG. 5. Eastern entrance to Cope quarry. Light colored Dako'a sandstone at top underlaid by chocolate-colored shales with remains of Camarasaurus.

A number of other bone-bearing horizons have been detected, but as yet they have not been sufficiently prospected to determine their richness. Heretofore the entire series and the succeeding Dakota formation has been considered as of fresh water origin. But on his last visit to this locality the writer discovered casts of shells of Ino-

ceramus in sandstones lying above the Marsh quarry and below the bone-bearing horizon at the "Nipple." These remains, only two in number, were not found in situ, and it is impossible to determine at present the horizon to which they belong. From the general appearance of the fragments of sandstone on which they were found I believe they came from the Jurassic, though they may possibly have come from a horizon which by some would be placed in the Dakota, though I must confess my total inability to place any limit to either the top of the Jurassic or base of the Dakota in this region, having experienced the same difficulty encountered by Mr. Darton in the hogback near Buffalo Gap in the Black Hills of South Dakota where he has found dinosaur bones in strata which he thinks may be either Jura or Dakota. I have also examined this latter locality and find the conditions very similar to those in Garden Park and the cañon below. I see no more reason for placing the dinosaur beds near Buffalo Gap in the Lower Cretaceous as has been suggested by Darton than for placing those of the region under discussion in the same formation. The difficulty it seems to me lies in the want of a realization of the fact that different conditions prevailed simultaneously over different though often adjacent regions and caused the simultaneous deposition of different materials. Along the streams and about the shores of the greater bodies of water deposits of sandstone would predominate, while in the quieter waters and especially off shore the finer materials would be thrown down to form the clays and shales of the same series. Wherever we find these shore deposits constituting the Jurassic strata we encounter the same difficulty in separating the Jura from the Dakota, for sedimentation then seems to have been continuous throughout the two periods and we are brought to the question as to the equivalents at such localities of the Lower Cretaceous. Could not the rocks of these two formations in part at least represent the fresh water and land equivalents of the marine deposits belonging to the Lower Cretaceous? Fresh water and marine conditions must have always prevailed, as at present, at the same time over different parts of the earth's surface, though thus far there has been little attempt on the part of geologists and paleontologists to correlate them, each series having as a rule been assigned to a distinct period in the time scale, though it is none the less certain that every marine formation has been accompanied by contemporaneous though more constricted fresh water deposits and that remnants at least of most of such deposits are still

preserved can hardly be doubted, indeed we may be quite positive that every fresh water or æolian deposit of whatever age has its marine equivalent, and the writer sees no reason why the lower members of the dinosaur beds of Garden Park, should not be the equivalents of the marine Baptonodon beds farther north, while the upper dinosaur beds of the same region and the entire series of dinosaur beds farther north would become the equivalents of the marine Lower Cretaceous. That the lowermost dinosaur beds of Garden Park are of an earlier age than those of Como Bluff in southern Wyoming and Piedmont, South Dakota, as well as of the other localities lying to the north, will I think be clearly demonstrated when we come to make a comparative study of the dinosaur remains from each. From the foregoing remarks it will readily appear that in the Garden Park region the problem of separating the Jura from the Cretaceous becomes a difficult one, the top of the Dakota becomes the natural dividing line, whether considered lithologically or paleontologically, and I have no doubt that these difficulties will be further enhanced by the discovery of dinosaur horizons throughout the entire upper series of sandstones and shales which we now consider as belonging to the Dakota. This is almost sure to follow as a reward for a patient and careful search in these beds, and will be most welcome as adding one more link in connecting the long gap which at present exists between Jurassic and Laramie dinosaurs. Of the history of American dinosaurs from the close of the Jura to the beginning of the Laramie we at present know nothing, save *Claosaurus agilis* Marsh from the Niobrara of Kansas and a few remains, for the most part quite fragmentary, described by Leidy, Cope, and Marsh, from the Cretaceous marls of New Jersey and North Carolina.